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Operator Contributions to Innovation: Supporting Innovative Production Development in a Digital Learning Environment

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Abstract. As all technologies come to pass, change by innovation is needed both ways, exploiting current knowledge to do better and exploring new knowledge to do differently. Due to years of continuous improvement (CI), exploitation of current knowledge in production development is rather well investigated, exploration is less. It could be argued that not utilizing the potential explorative operator contributions to production innovation is a lost opportunity to increase a company's innovation capability. Simultaneously, operators are facing great changes when manufacturing is adopting to digitalization and sustainability challenges enhancing the need for production innovation. This study focused on a team of operators through a workshop series of five sessions about explorative activities in a format using structured and semi-structured interviews. The study provided a basis for constructing a model for positioning operators' both digital and explorative maturity level. Through the empirical data and the model, the conclusion is illustrated as alternative pathways to reach a desired level of operator maturity. It was concluded that approaching digital and explorative maturity for operators should be done as a two-step process. Increasing both maturities simultaneously, as with the studied team, showed difficult due to the digital and explorative maturity being co-dependent. The suggested two-step process contributes to a better understanding of prerequisites and opportunities for operators to participate and contribute to production innovation in digitalized work environments, ultimately increasing the company's innovation capability.

Keywords. Production development, production innovation, online tools.

1. Introduction

Innovation is increasingly recognized as a strategic asset for manufacturing firms. Firms needs to reach for greater innovation capability to achieve a sustainable development of their business. This entails being aware of the need to change and being able to change [1]. Being able to change typically means being able to exploit and explore, being able to change by *doing better* and by *doing differently*.

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In manufacturing industries, the main initiative responsible for change – production development – has during the last decades focused heavily on continuous improvement (CI). Within the programs of CI, attention to remove waste and creating value is of greatest importance [2]. Developing and implementing incremental changes that exploits current knowledge to change production in a slow and safe manner. Meaning, focusing on the ability to change by *doing better*. This have yielded beneficial results as many companies have learned ways to optimize their production and becoming faster, more cost-efficient and on worth. The importance of involving operators in production development is well documented in continuous improvement literature as their familiarity with operations is key to incremental optimization.

On the other side, change by *doing differently* would then involve exploring new knowledge, taking risks, ambiguity and develop through play [3]. Less literature has focused on company-wide employee participation in more explorative developments though creativity and problem-solving skills are suggested to reside in every individual [4]. It could be argued that inadequate utilization of employees' contributions results in a reduced overall innovation capability of an organization.

As all technologies come to pass, the ability to change by *doing differently* has to be recognized [5]. In this, ambidexterity, the ability to combine *doing better* and doing differently is a key [6]. In increasing innovation capability, the dynamics between the operator's current way of working and more explorative ways must be further investigated to better utilize their potential contributions.

Simultaneously, manufacturing industries are in the midst of a digital transformation. Cyber-Physical Systems (CPS) are suggested to be extensively implemented the production systems and operator's roles are expected to change within manufacturing [7]. This digital environment presents new challenges regarding operator's involvement and contributions. Innovation is suggested to be a great factor of success within digital transformation which makes it highly relevant to further understand the dynamics between explorative developments and digital maturity.

A workshop series intended to support explorative production development through involvement of operators was during 2020 interrupted by the global pandemic of COVID-19. Due to national restrictions the workshops were held virtually, piloted via a virtual meeting platform. In the light of the digital transformation, understanding operator's ability to be involved through digital environments is crucial.

Thus, this study offered an opportunity to investigate the involvement of operators in more creative and digital production development, based on its current state. What opportunities and challenges the simultaneous need for creative and digital operators might present.

Purpose, Aim & Research Questions

The purpose of this study was to better understand how operator contributions to production innovation are affected by digitalization. Thus, the aim was to investigate the operator's experiences with working more exploratively in a digitalized learning environment to identify potential challenges and opportunities in that specific context. The research question was thus formulated:

> RQ: How can the involvement of operators through digital environments be described in production innovation management?

Contribution

A model provides a better understanding of prerequisites and opportunities for operators to participate and contribute to production innovation in digitalized learning environments. Through this model the present paper is an initial contribution to support of increased, sustainable innovation capability aiming to endure the future of digitalized work environments for operator contributions in production of manufacturing based on empirical findings.

2. Methodology

The study was conducted at a fabricated metal manufacturer in Sweden and was initiated through two preparatory meetings with site managers and leaders. The two one-hour meetings were digital and gathered all leaders to be briefed regarding purpose and structure of the upcoming workshops, as well to instruct them in coaching leadership as in coaching kata [8].

Then followed a series of five separate workshops involving a team of 12 operators, their team leader and production manager. No workshop had all 12 operators attending due to shift work, all workshops had at least 8 attendants. Each workshop spanned 1 to 3 hours and included short seminar sessions followed by discussions and then practicing different explorative methods. The workshops were focusing on different phases of a design process with the goal to increase creativity and exploration in production development. These workshops utilized digital online tools to enhance creativity and innovation work, such as an interactive and real-time quiz tool ("Mentimeter.com") and an online whiteboard ("Mural.co") in addition to using the digital meeting platform "Microsoft Teams". All authors of this paper were, to some extent, involved in these workshops. The first author was positioned as an observer, documenting discussions in the workshop, the second and third author were engaged in the exercises and presented the short seminars and supported the attendees in documenting the workshop results in Powerpoint and Mural. The fourth author partook in the structuring and planning but did not participate in the workshops.

The workshops were later followed up by 7 semi-structured interviews with a few of the participants of the workshop series and observations on the shop floor. The second author performed the interviews and observation on-site while taking simple notes in table format similar to table 1. Meanwhile, the first author participated digitally, and audio recorded the interviews, took notes and transcribed the interviews afterward. The aim of the interviews was to further investigate operator's and manager's impressions and reflections regarding the contents and formats of the digital workshops, concerning innovation and digitalization. The 7 interviewees were chosen depending on attendance at work at the available interview occasion. Due to pandemic travel restriction and the shift schedule, only seven who were at work were interviewed. The interview guide was developed through the theoretical framework based on current understanding regarding prerequisites for creativity/exploration. The questions were divided in three sections:

- Being creative in production development
- Training and education
- Digital maturity

The main aim of the interviews was, again, to understand how the participants experienced the digital/virtual aspect to affect their capability to be creative and, to higher degree than usual, explore alternative solutions. The data collection, alongside observations by the researchers, illustrated differences between the targeted participant groups. Opportunities and challenges in the involvement of operators in more explorative and digitalized production development.

3. Theoretical framework

The theoretical framework was designed to act as a basis for better understanding the current context involving production development and creativity as well as understand relevant aspects that are suggested to follow digitalization. Together, this improved overview of relevant elements of a current and a future, desired situation offered an enriched analysis allowing the construct of a conceptual model.

3.1. Operators and production development

Within manufacturing companies lean manufacturing is currently the most common operations management paradigm [9]. Guided by implementing company tailored lean production systems, XPS, where X stands for the company name [10]. The improvement focus is on CI where companies have learned ways to optimize their production and becoming more efficient.

Whether company innovation is incremental as in CI or more radical, it includes internal innovation capabilities (e.g. company R&D) and external innovation capabilities through collaboration with e.g. consultants [11]. An important innovation capability is the ability to switch between incremental and more radical approaches, or ambidextricity [6] A prerequisite for successful innovation leading to implementation of new knowledge are fostering the sources of new knowledge as well as developing internal innovation absorption capacity within the company [12], [13].

The importance of involving operators in production development is well documented in continuous improvement literature [14] as their familiarity with operations is key to incremental optimization. The success factors of CI include training managers and employees, investing in time and tools for improvement, and involving all employees in CI activities [15]. Less literature has focused on company-wide employee participation in more explorative developments. The benefits of high involvement innovation (HII) are considerable, although reaching a high involvement and turning the company into a mature learning organization requires time and "heart" from leaders and managers [16]. The HII literature also considers operator contributions to be exploitative and incremental [1], running the risk of not utilizing potential explorative abilities.

3.2. Operators and innovation

Innovation management (IM) shares many similarities with CI, perhaps to no surprise as CI – or development of incremental change rather – can be viewed as a type of innovation. However, since IM is suggested to contain additional key aspects/factors involving the larger spectrum of innovations, not bound to incremental developments only. Perhaps most noticeably found in suggested key factors for IM [16] such as:

1. Creativity and idea management (managing both incremental *and* radical ideas),
2. Organizational intelligence (use knowledge and ideas to handle uncertainty/ambiguity)
3. Culture and Climate (Tolerating ambiguity, creative time, et cetera)

It could be argued the extension of key factors through IM, in practice, is about managing creativity, which in the context of production development is the capability to explore more alternative solutions. The ability to be creative is suggested to reside in all humans and derives from three aspects: 1) Expertise, 2) Motivation and 3) Creative thinking skills [4]. Motivation is claimed to be the only of the three that an organization is able to affect and manage. Managing motivation is described as managing: 1) Challenge, 2) Freedom, 3) Resources, 4) Work-group features, 5) Supervisory encouragement and 6) Organizational support. However, creative-thinking skills and expertise are abilities that arguably could be learned and exercised if given the education and training.

3.3. Operators and digital maturity

In communication and learning, also for manufacturing operators, digitalization and use of digital tools has increased lately. Visual digital tools have proven successful in supporting improved learning of new manual production tasks [17]. This is expected to be achieved, foremost through the implementation of new digitalized work, better utilizing human strengths and covering for human weaknesses [7]. Digitalization has also been suggested to, from a broader perspective, shift the required skillset of operators, as their previous tasks are replaced by higher-order tasks [18]. However, the success of digitalization is dependent on the digital readiness of the whole company [19].

In an effort to understand potential consequences of this future scenario insight regarding critical success factors (CSFs) was collected from digital transformation literature. Identifying factors relating to the role of operators, which provided a list of four main factors: 1) Innovation culture & activities, 2) Project management (management support, team competence and composition, clear and defined plan/goals), 3) Training/Education/Experience and 4) Internal communication [20], [21], [22].

4. Findings

To present an overview of the results of the interviews, the answers to structured questions are summarized in the following table (see Table 1). Please note that the interviews were carried out in Swedish, thus, formulations of questions and answers are translations.

Table 1. Quantative summary results from interviews with participants of the workshops (Operators, N=5, and leaders, N=2)

Questions	Operators	Leaders
1. Do you have a company-provided cellphone and/or computer?		
Yes		2
No	5	
2. How did you experience being involved in creative exercises?		
Positive	3	2
No opinion	2	
3. What is your standpoint on the company promoting creative exercises in your work?		
Positive	4	2
No opinion	1	
4. Are you currently offered resources (time, tools, competence, etc.) allowing you more creativity?		
Yes		2
No	5	
5. Are you offered continuous education/training for your daily tasks, creative problem solving and/or managing digital technology/communication?		
No	5	2
6. How much of your daily work is currently digital?		
Less than 30%	5	2
7. How does it affect your ability to be creative when working digitally?		
More difficult	1	1
Both more and less difficult		1
No difference	4	
8. How does it affect your motivation when working digitally?		
Negatively		1
Both negatively and positively	2	
No difference	2	1
Do not know	1	
9. Is it more or less difficult to control your way of working when working digitally?		
More difficult		2
No difference	5	
11. Are you aware of any goals and/or KPIs to follow up on continuous improvement?		
Yes		2
No	5	
12. Does it affect your goals and/or KPIs when working digitally?		
No	4	2
Do not know	1	

A few questions of the interviews were asked open-ended. An overview of the answers to those questions are provided and represented using selected quotes (see Table 2). Please note, as stated in previous paragraph, the interviews were carried out in swedish, thus, the questions/answers are translated.

Table 2. Representative quotes from open-ended questions of the interviews

13. What do you consider to be have been the value of the workshops?	"It is interesting but nothing I imagine I'll bring into my actual daily work. But I think more of it [problem solving in groups] would be positive". – Operator B "Working in groups. Everyone could put forward different solutions." – Operator C "Allow seeing further than where I currently am." – Operator A
14. Do you currently work in any similar way [as in the workshops]?	"Yes, that would be every Tuesday at 11. A lean-/improvement-meeting. However, I feel there is no engagement. You only hear 'there is no time'." – Operator B "Perhaps in some sense within an internal project group but far too little on operator level" – Leader B
15. What did you think of working digitally [as in the workshops]?	"I felt Menti [the digital tool] was good. I think it's easier to express and to have opinions when you're anonymous" – Operator E "It [working digitally] feels so unnatural and I'm so bad at computers and all that." – Operator C
16. How did working digitally affect your production development process?	"It would probably have been more efficient [doing it non-digitally]. It felt slower with a computer between us." – Operator D "As I've said, I thought it was difficult having everyone in groups, then subgroups, coming up with ideas… it's difficult digitally. Education and seminars etc. are better suited for digital meetings." – Leader B
17. How did working digitally affect the dynamics of the group?	"In the beginning I didn't feel like it was working out but it got better the further we did it." – Leader A "Other [non digital] times have worked better than this. I would say this ended up uninvolved and a bit silly on the operator's part. As I said earlier, we were mostly like: Are we even supposed to be here?" – Operator B
18. Have you seen any changes in your work since the workshops?	"As I've said, the ideas have become bolder and they have more thoughts on solutions that wasn't showing before." - Leader A "It is not as quiet anymore. Before, it was dead silent [in the weekly meetings]" – Operator A "Nothing except the solution that was developed. I feel like there is no one driving it forward. It feels uninvolved." – Operator B

4.1. Discussion

First, regarding digital practices, the operators had a hard time to participate due to the lack of devices (hardware), experience and prior training with the digital tools (software). Foremost, the lack of company-provided smartphones and personal computers made it virtually difficult for the operators to participate individually. Through most activities the operators had to participate in groups, sharing devices. Which led to distancing the individual from the meeting and made it more difficult to participate in the explorative activities. Some of the sessions also suffered from disconnected participants which clouded the innovative climate and reduced employee participation/engagement, in accordance to [16]. Making it difficult for individuals to speak out or dare to be more explorative. Non-relevant small talk disrupted main discussions and ridiculing activities silenced others. According to found literature, these were critical conditions, insufficient for successful digital maturity [20],[21].

However, digital tools such as Menti got several positive remarks in that regard by participants as it provided them the ability to answer anonymously. The virtual platform itself had implications for the facilitation of the workshops. The digital aspect offered a level of access, allowing the multiple workshops in a rather short timeframe, which would otherwise have been difficult due to travel and scheduling. Regardless, the digital format seemed to put more responsibility on the participants as they felt a greater distance and less supported by the facilitators. This could still have worked if operators were more digitally mature, had better acess to devices and training in the tools[19],[20].

Second, regarding the explorative work, overall, creativity was seen as something positive and value-adding. The participants valued the ability to further explore alternative solutions as well as the general positive social effects it had on the culture and climate. Several operators did, however, express that they are not offered enough resources – such as time, tools and/or encouragement – to be creative, hinders also mentioned in litterature [15]. Simple, quick and easy-to-implemented solutions seems to be promoted in the weekly meetings of production development. Training and education is another resource not offered for creativity nor for digital tools. Even training for the operative work itself was not offered in a structured or regular manner. Again, according to screened literature, these are considered critical abilities, lacking for succesful explorative maturity [16].

Currently the operators have close to no digital communication in their daily operations except for when running the manufacturing execution systems on their machines. Every operator claimed to have preferred physical/analog interaction versus the digital. Despite this, no one felt as if the digital format affected their creative-thinking skills, motivation, freedom or goals [16]. The most mentioned effects were feeling disconnected to facilitators of the workshop and difficulties working via the digital tools. The group dynamic was perceived to be more disoriented by several participants, hinting at the digital barrier as distancing and flattening of the hierarchy, in line with [19]. Resulting in the group being occasionally distracted, not respecting the facilitators or the workshop activities. Except for the implementation of a solution developed through the workshops a few participants feel that nothing has changed. Other participants, however, experience a shift in commitment. The frequency of ideas and their *boldness* from operators had supposedly increased at the weekly meetings.

The findings of this study suggests the operator's lack of support (equipment, tools and training) to reach sufficient levels regarding both explorative and digital maturity was a – or perhaps the – major issue. Support, such as equipment, tools, managerial

encouragment, training and education are important [19]. These aspects could be crucial in describing the involvement of operators in production innovation management. As a visual representation a conceptual model with two dimensions, digital maturity and explorative maturity was formalised (see Figure 1).

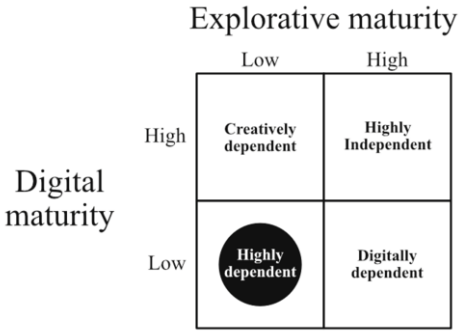

Figure 1. Operators digital and explorative maturity based on company-provided support and positioning the studied team (black circle).

Establishing the two sought maturities as dimensions, the presented model divides the spectrum into two levels; high and low. In the scenario of low leveled maturity for both digital and explorative capabilities, the operators are classified 'highly dependent'. This refers to operators being poorly support in both dimensions and thus not performing optimally in either. The operators were unable to work digitally and were thus hindered to contribute to the innovation capability in an explorative manner. In the opposite scenario of high digital maturity and high explorative maturity, the operator would be seen as highly independent. This would mean the operators are trained and educated, offered the encouragement, time equipment and tools to work digitally and despite the distance created by technology, able to contribute to innovation through exploration. In the case of high maturity regarding one ability and low for the other, the operators are classified part-dependent. If low maturity for explorative development, the model labels them "creatively-dependent", i.e., digitally able but in need of constant support in order to contribute to the innovation capability through exploration. If they posess high explorative maturity but instead low digital maturity, the model instead labels them "digitally dependent". Meaning, able to contribute to innovation capability through exploration but not in a digital environment.

Positioning the studied team, the proposed model labels them as "highly dependent" (see black circle in Figure 1) due to the lack of support expressed in the findings. This means that the lack of digital maturity may be a hinder to develop explorative maturity and the lack of explorative skills may be a hinder to develop digital maturity. In practice to overcome this the suggestions from interviews and participation reflection is to either first do a separate individual training in digital learning tools (supplying equipment, software and training) before the explorative innovation team training or to do explorative innovation team training on-site and then introce digital tools as needed for the innovation implementation. To try both simultaneously on a distance was not percieved optimal by the atendees in this case study.

5. Conclusion

In a greater sense, high digital maturity and high explorative maturity enables inclusion in production development. The accessibility for all parties, leveled hierarchies within teams and utilization of more individual creative potential offers opportunitities for increased innovation capability. In the process of acquiring these maturities, based on the present model and positioning the studied team it is concluded that it should be done as a two-staged rocket (see Figure 2 below).

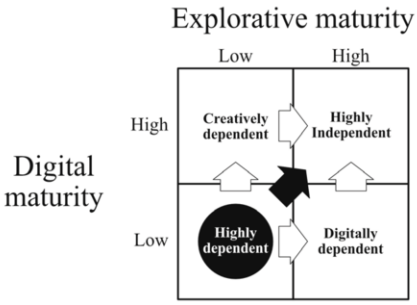

Figure 2. Conceptual model describing the position of studied team and possible routes to a more desirable position.

As the abilities seem co-dependent, the empirical findings indicates that approaching them both, simultaneously (see the diagonal arrow in Figure 2), is difficult . Since digital maturity, in this context, is what allows interaction in the digital learning space, activities can not efficiently occur if digital maturity is low.

Instead, firms should focus on increasing one of the maturities and become comfortable and sufficient with it before moving on, increasing the next one. Either through alternative one, provide training, education, tools, time, space and managerial support for explorative activities until there is a certain comfort in working continuously more “creatively” in production develepment. Then learn and adopt digital work environments and tools to learn conducting production development in a digital setting. Alternative two, being the opposite then starts with adopting digital work through increasing digital maturity of the operators. Providing resoruces and support, and when it is sufficient take on working more explorative in that digital setting. The second option seems favourable in a pandemic setting or when innovation trainers are very remote, where digital tools are the main option or training.

5.1. Considerations

This study is empirically based on the participants experiences, investigating the dynamics between operator’s practice and a digitalized practice by asking the operators themselves. There is a risk of individual interviewee biases against overall change, digital technologies, creativity, et cetera. Perhaps especially due to lack of training, education and experience which might reflect an excessively negative stand towards both innovative and digital practices.

Also, the study has so far been conducted at a single company which therefor runs the risk of providing the research with highly contingent data and findings. To make findings more universal, the study could be expanded by other researchers in the future.

Future research should factor in different industries, company size, organizational structure, et cetera.

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References

[1] J. Tidd and J. Bessant, *Managing Innovation*, 5th ed. John Wiley & Sons, Ltd, 2014.
[2] N. Bhuiyan and A. Baghel, An overview of continuous improvement: from the past to the present, *Management Decision*, 2005 Jun;43(5): 761–771..
[3] J. G. March, Exploration and Exploitation in Organizational Learning, *Organization Science*, 1991 Feb; 2(1): 71–87 .
[4] T. Amabile, How to Kill Creativity, In: *Creative Management and Development Creative management and development*, London United Kingdom: SAGE Publications Ltd, 2006, pp. 18–24.
[5] R. N. Foster, Timing Technological Transitions. *Technology in Society*, 1985;2–3(7): p. 127–141.
[6] Hedman, M., Larsson, L., & Rönnbäck, A. Ö., Opportunities for Managing Incremental and Radical Innovation in Production. Procedia CIRP,2021; 104: 756-761.
[7] D. Romero *et al.*, Towards An Operator 4.0 Typology: A Human-Centric Perspective on the Fourth Industrial Revolution Technologies, In: *Proceedings of the international conference on computers and industrial engineering (CIE46)*, 2016p. 1–11.
[8] M. Rother, Toyota kata: managing people for continuous improvement and superior results. McGraw-Hill Professional, 2010.
[9] M. Kurdve and M. Bellgran, Green lean operationalisation of the circular economy concept on production shop floor level, *Journal of Cleaner Production*, 2021;278: p. 123223.
[10] Netland, T., Exploring the phenomenon of company-specific production systems: one-bestway or own-best-way? *International Journal of Production Research*, 2012; p.1-14.
[11] Bessant, J. and Rush, H., Building bridges for innovation: the role of consultants in technology transfer, *Research Policy*, 1995; 24(1):97-114.
[12] Serrano-Bedia, A.M., Concepcion Lopez-Fernandez, M. and Garcia-Piqueres, G., omplementarity between innovation activities and innovation performance: evidence from Spanish innovative firms, *Journal of Manufacturing Technology Management*, 2012;23(5):557-577.
[13] Zahra, S.A. and George, G., "Absorptive capacity: a review, reconceptualization, and extension", *Academy of Management Review*, 2002;27(2):185-203.
[14] T. H. Netland, Critical success factors for implementing lean production: the effect of contingencies, *International Journal of Production Research*, 2016 Apr; 54(8):2433–2448.
[15] J. Bessant and S. Caffyn, "High-involvement innovation through continuous improvement," *IJTM*, 1997; 14(1): p. 7.
[16] B. Lawson and D. Samson, "Developing Innovation Capability In Organisations: A dynamic capabilities approach", *Int. J. Innov. Mgt.*, vol. 05, no. 03, pp. 377–400, Sep. 2001.
[17] Kurdve, M., "Digital assembly instruction system design with green lean perspective-Case study from building module industry." Procedia CIRP, 72, 762-767, 2018.
[18] C. B. Frey and M. A. Osborne, "The future of employment: How susceptible are jobs to computerisation?," *Technological Forecasting and Social Change*, vol. 114, pp. 254–280, 2017.
[19] Machado, C. G., Almström, P., Öberg, A. E., Kurdve, M., & Almashalah, S. Y., "Maturity Framework Enabling Organizational Digital Readiness", In SPS2020 (pp. 649-660). IOS Press, 2020.
[20] A. C. Shinohara, E. H. D. R. Da Silva, E. P. De Lima, and F. Deschamps, "Critical Success Factors for Digital Manufacturing Implementation in the Context of Industry 4.0," *Proceedings of the 2017 Industrial and Systems Engineering Conference*, p. 7, 2017.
[21] S. Nurbossynova, A. Sautbekov, B. Zholdaskhan, Y. Abdallah, and E. Shehab, "Critical Success Factors of Digitalization of Kazakhstan Manufacturing Industry," in *2021 IEEE International*

Conference on Smart Information Systems and Technologies (SIST), Nur-Sultan, Kazakhstan, Apr. 2021, pp. 1–6.

[22] R. Pozzi, T. Rossi, and R. Secchi, "Industry 4.0 technologies: critical success factors for implementation and improvements in manufacturing companies," *Production Planning & Control*, pp. 1–21, Mar. 2021.